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DIVISION OF SAFETY RESEARCH (DSR)  
TESTING AND CERTIFICATION BRANCH (TCB)  
FIELD INVESTIGATIONS GROUP (FIG)

FIELD RESEARCH REPORT ON THE PERFORMANCE OF MSA  
POWERED AIR PURIFYING RESPIRATORS ON SILICA FLOUR  
BAGGERS AT ILLINOIS MINERAL COMPANY  
ELCO, ILLINOIS

by

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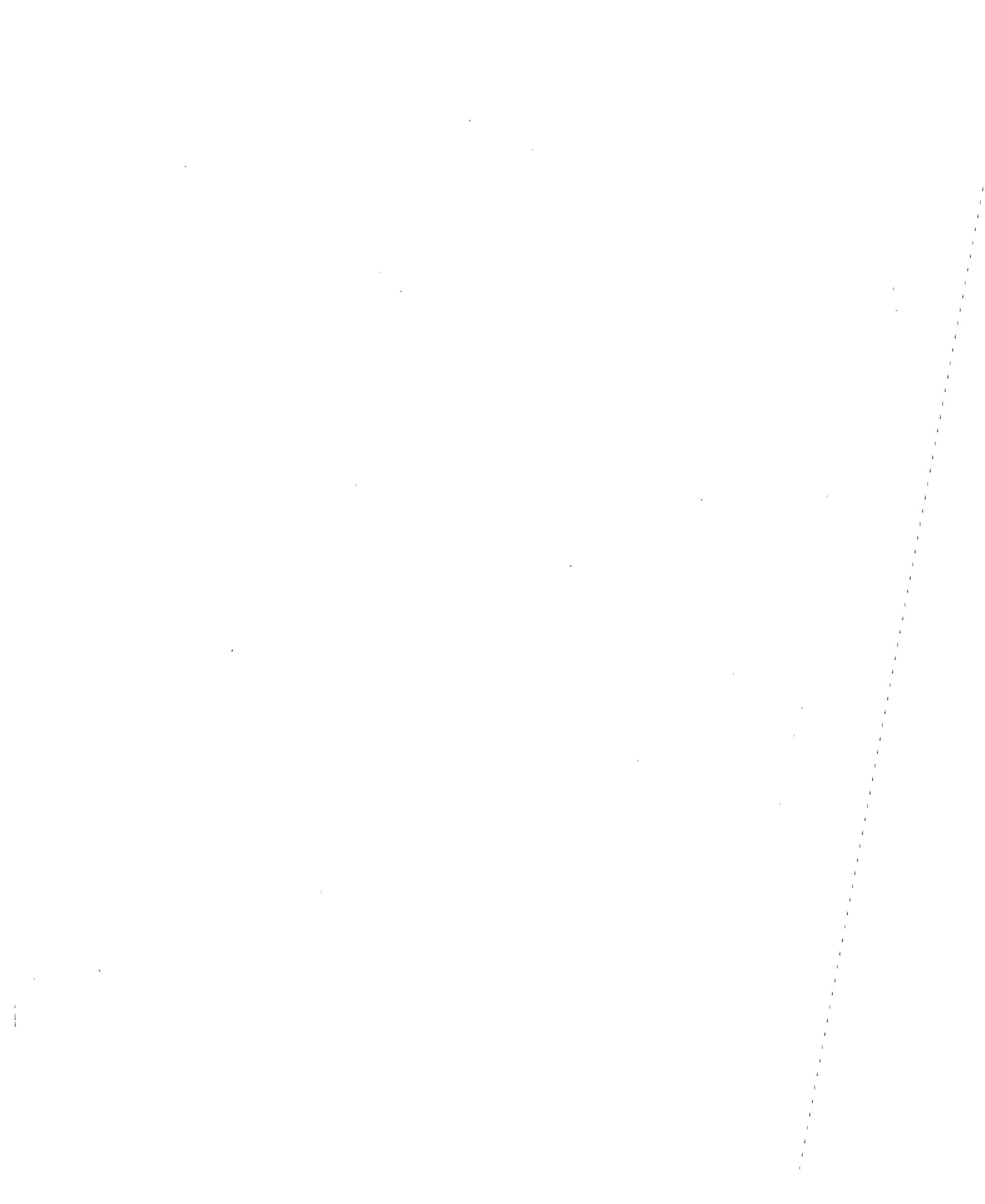
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## Abstract

### Field Research Report on the Performance of MSA Powered Air-Purifying Respirators on Silica Flour Baggers at Illinois Mineral Company, Elco, Illinois

In December 1980 the Division of Safety Research (DSR), Field Investigations Group (FIG), received a request from the Illinois Mineral Company, Elco, Illinois to investigate problems this company was having with the Mine Safety Appliances (MSA) Company's Powered Air-Purifying Respirator (PAPR) not providing proper respiratory protection to workers employed in silica bagging operations. Results of data collected and visual observations made during the course of the laboratory test and field evaluation of the MSA PAPR showed that this respirator system did not provide the workers the required respiratory protection. Recommendation was made to MSA and Illinois Minerals that use of the MSA PAPR be discontinued in the bagging of refined silica and similar type operations until design problems associated with performance of this respirator system was rectified.



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FOR ADDITIONAL INFORMATION, PLEASE SEE THE ADDENDUM ATTACHED TO THIS REPORT TITLED "WRITTEN RESPONSE TO POINTS OF ALLEDGED EXPERIMENTAL ERROR" DATED MAY 1981.



## I. INTRODUCTION

In December 1980 the Division of Safety Research (DSR), Testing and Certification Branch (TCB), Field Investigations Group (FIG), received a request from Mr. William R. Fox, Environmental Control Supervisor, Illinois Mineral Company, to investigate problems his company was experiencing with a large number of the Mine Safety Appliance (MSA) Company's Powered Air Purifying Respirator (PAPR) systems, NIOSH/MSHA Testing and Certification Approval No. TC-21C-186. Illinois Mineral Company had procured these units for use by their workers who were employed in the bagging of silica flour at their Elco Illinois plant operation. At the time of the complaint, Illinois Mineral Company submitted to NIOSH an MSA PAPR illustrating the problem they were experiencing. From this submitted unit, it was observed that large quantities of particulates were on the grommets, necks of the high efficiency filter cases and inside the motor blower housing (Photograph 1).

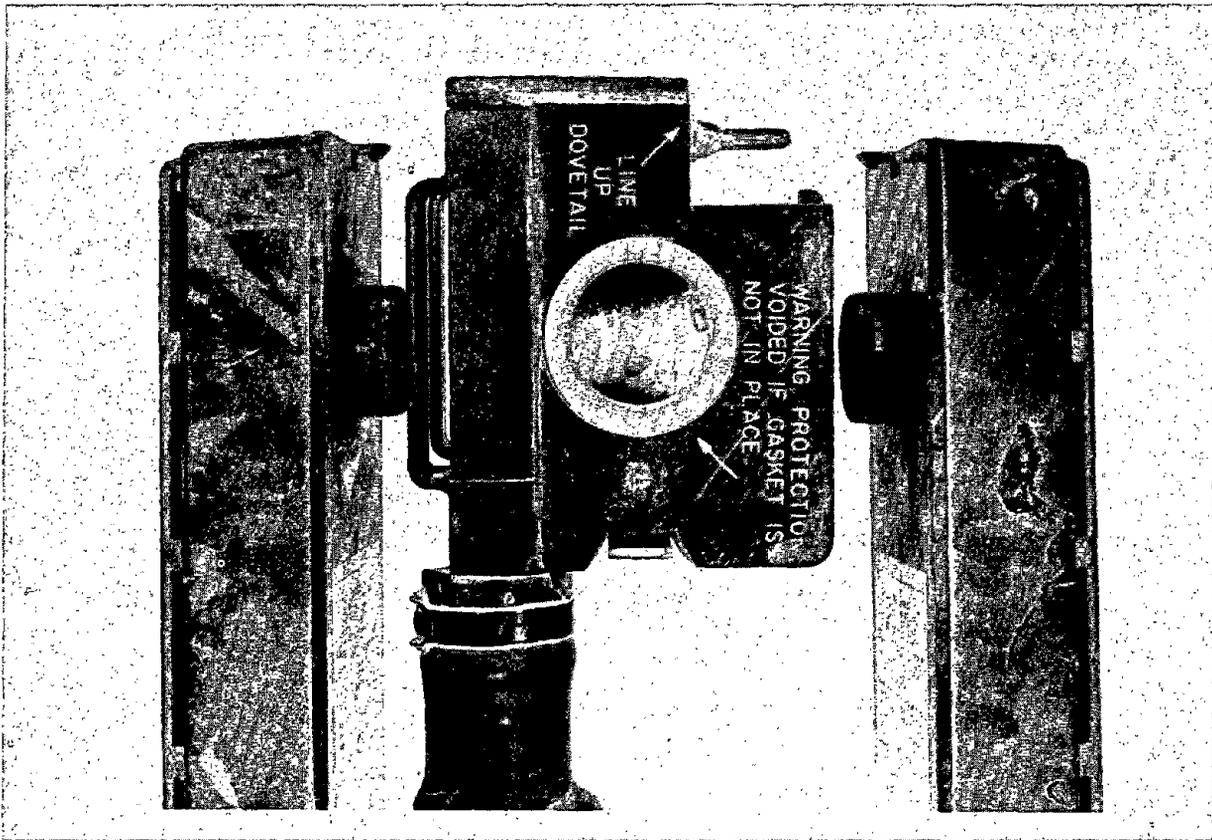
In response to this problem and request, a field investigation was conducted at the Illinois Mineral Company's Elco Illinois silica plant during the period of January 27-30, 1981, to investigate the subject complaint and assess the performance of the MSA PAPR under actual field use conditions.

As a part of this investigation, quality assurance and performance evaluation tests were also conducted on the MSA PAPR in the NIOSH Testing and Certification Branch laboratory in Morgantown, West Virginia.

This report reflects:

- 1) results of laboratory evaluation of the engineering design specification for the MSA PAPR;
- 2) results of laboratory performance tests of the MSA PAPR;
- 3) results of evaluations of the MSA PAPR tested under actual field use conditions;
- 4) evaluation of the Illinois Mineral's Elco, Illinois silica plant's Respiratory Protection Program;
- 5) recommendations to the MSA Company to correct observed design problems associated with the MSA PAPR and its ability to afford respiratory protection to workers against exposure to concentrations of airborne silica dust in the work environment;
- 6) recommendations to the Illinois Mineral Company for increasing the effectiveness of their respiratory protection program.

The sampling protocol used and resulting data collected during the course of this evaluation were for the specific purpose of assessing the performance of the MSA PAPR under actual field use conditions and not for compliance purposes.



**Photograph 1.** Particulates on grommet and necks of high efficiency filter case and motor housing of Illinois Mineral MSA PAPP system.

## II. PROCESS DESCRIPTION

Ore deposits in southern Illinois are reported to contain approximately 99% silicon dioxide,  $\text{SiO}_2$  (1). Mineralogically, the deposits are microcrystalline quartz. The Illinois Mineral Company's raw materials are mined underground and transported to the Elco Processing Plant located a few miles away from the mining site.

At the plant, the raw ore is crushed, dried, milled, and blended to yield the desired quality of product which is then stored in bins until ready for bagging. The final product is commonly referred to as silica flour.

Bagging consists of filling fifty pound bags at three locations -- two single bagging spouts, spout A and spout B, and a tandem two-spout bagger where two bags can be filled simultaneously. (Fig. 1) After being filled, the bags are stored on pallets for shipment. Approximately 15 tons of silica flour are bagged by each bagger during an eight-hour work shift.

### III. METHODS AND MATERIALS

Laboratory testing for quality assurance and performance and field evaluations were conducted on 3 MSA PAPRs (identified in this report as 47, 48, and 49) and 36 MSA PAPR high efficiency filters (procured commercially from the open market) as an overall assessment of the ability of the MSA PAPR to afford proper respiratory protection to workers when exposed to concentrations of airborne silica dust in the work environment. The MSA PAPR system consists of a powered air purifying unit (high efficiency filter, blower and hose assembly) plus a facepiece.

#### A. Laboratory Quality Assurance and Performance Evaluation

1) Laboratory Quality Assurance - Dimensional analysis measurements were performed on the grommets of the motor/blower housing and necks of the high efficiency filter cases of the MSA PAPR units to determine if they meet MSA's engineering design specifications. The scope of dimensional analysis for this evaluation consisted of measuring the outside diameters (OD) of the necks of the plastic high-efficiency filter cases and the inside diameters (ID) of the upper and lower ends of each grommet, designated in Appendix 1 as UG and LG. The UG or upper grommet, designates the area of the grommet nearest to the outside of the motor/blower housing next to the filter case and the LG or lower grommet designates the tapered end of the grommet nearest to the inside of the motor/blower housing.

The dimensional analysis measurement techniques used were identical to those specified by the MSA Classification of Defects Inspection Procedure for the necks of the high efficiency filter cases/filter holder (2) and grommets (3) of the MSA PAPR.

2) Laboratory Performance Evaluation of the MSA PAPR system was conducted in conformance with 30CFR, Part II, Subpart K, Section 11.140.4 dated March 25, 1972.

The three MSA PAPR units, 47, 48, and 49 were evaluated in a silica dust chamber at average challenge concentrations of 50.3, 50.6, and 60.6 milligrams of silica dust per cubic meter of chamber air ( $\text{mg}/\text{m}^3$ ) respectively. The mass median diameter of the silica chamber dust used was 2.2 $\mu\text{m}$  and had a standard geometric deviation of 2.8 $\mu\text{m}$ .

Both MSA half (Comfo II) and full (Ultra View) facepieces were evaluated with the MSA system's powered air purifying unit (blower, high efficiency filters and hose assembly).

For testing, the respirator facepieces were fitted to standard formed heads entrained to an air sampling unit supplied with pre-weighed 76mm absolute filters to collect/detect particulates that penetrate the PAPR system during the test period.

Although the blower of the MSA PAPR system supplied a minimum of 4cfm (113 l/min) to the facepiece, a mechanical breather calibrated to breathe at a flow rate of 40 l/min. was connected to the head to simulate a 622 kp-m/minute work rate breathing pattern inside the respirator facepiece.

After the test period, the 76mm air filter was reweighed and the concentration ( $\text{mg}/\text{m}^3$ ) of particulates penetrating the respirator system was calculated. With this information and the knowledge of the average challenge concentration ( $\text{mg}/\text{m}^3$ ) of silica dust in the test chamber during the test period, a System Protection Factor (SPF) was determined for the MSA PAPR tested under laboratory conditions.

Air flow measurements were made with a dry test meter on all three MSA PAPR units before and after each test period to determine if the required minimum average air flow of 4cfm was supplied to the facepiece throughout the test period.

## B. Field Evaluation

### 1) Personal

To determine the protection afforded the workers by the MSA PAPR during the routine bagging of silica, air samples were collected inside the facepiece (IFP) and outside the facepiece (OFF) to establish a System Protection Factor (SPF). For the purpose of this report, an "SPF" is defined as the concentration of silica dust measured outside of the respirator facepiece (mask) divided by the average concentration of silica dust measured inside the respirator facepiece during the sampling period.

Assessment of the MSA PAPR to afford proper respiratory protection to workers exposed to silica dust under field conditions was accomplished by evaluating two of the new MSA PAPR units, #47 and #49, while being worn by two workers employed in the bagging of silica at the two-spout bagger. One of the PAPR units worn by the workers was supplied with a Comfo II half piece and the other with an Ultra-view full facepiece.

Two separate, but identical, closed face filter, air sampling trains (Photographs 2A, B, C, and D) were used to simultaneously measure silica dust concentrations both inside and outside of half (Comfo-II) and full (ultra-view) facepieces worn by selected workers during routine silica bagging operations. The air sampling train consisted of a two-piece styrene filter cassette containing a 37mm pre-weighed FWS-B Poly Vinyl Chloride (PVC) filter connected to a personal air pump by a 2-foot length of 1/4" tygon tubing. Each pump was calibrated to provide an air sampling flow rate of 1.5 l/min.

IFP samples were collected by inserting the sampling inlet of the cassette into a modified luer adaptor probed through the center of the body of the half facepiece and through the face shield of the full facepiece. Air tight seals were achieved on both units by compression from a rubber washer and nut on the inside of the facepiece.



**Photograph 2 A. and B.** Personal OFP and IFP air sampling train utilizing the MSA PAPER Ultra-View full face piece.



**Photograph 2 C. and D.** Personal OFP and IFP air sampling train utilizing the MSA PAPER Comfo II half face piece.

OFF samples were collected by attaching a cassette filter holder to the worker's collar and positioning the sample inlet as close as possible to the worker's breathing zone. The sampling periods for both IFP and OFF samples were identical.

The sample protocol established dictated that the personal (OFF and IFP) air filter cassettes and respirator high efficiency filters be changed after each morning and afternoon work period and that the grommets on the blower housing be cleaned. The reason for changing the filters was that the caution instructions provided on each high efficiency filter unit required the replacement of the filter after each 4 hours of use or when the air flow supply through the system falls below 4 cubic feet per minute. In order to determine an accurate system protection factor for the MSA PAPR system, it was necessary to stop each PAPR and personal air sampling pumps during each break period. The average operating flow rate (cfm) was determined in the field by measuring the flow rate of the MSA PAPR units with a dry test meter before and after each work period. Beginning on the second day, this protocol was modified to evaluate one of the MSA PAPR units (#49) when using the same filter over two full work shifts. During this time, the filters were removed only when replacing the PAPR's discharged battery packs after each a.m. and p.m. work period.

## 2) Free Standing

The MSA PAPR unit (minus the facepiece) was evaluated to assess its performance when operated undisturbed in a fixed location. This was accomplished by operating two units over a full work shift in a general 4-8 foot radius of the two spout bagging operations where the two PAPR's were being evaluated on the workers. One of the two units tested belonged to NIOSH (No. 48) and the other to the Illinois Mineral Company which they had purchased for use in their respiratory protection program.

Assessment of the MSA PAPR unit's efficiency when operated in this mode was accomplished by substituting the facepiece of the PAPR system with an air sampling head supplied with a pre-weighed 76 mm filter to filter the air passing through the PAPR system over its full operating period. The efficiency of the PAPR unit was determined by observing the change in weight of the 76 mm filter over the sampling period. The average operating flow rate (cfm) was determined in the field by measuring the flow rate of the MSA PAPR units with a dry test meter before and after each work period. From this, the concentration ( $\text{mg}/\text{m}^3$ ) of total particulates penetrating the PAPR unit was determined.

3) Particle Size Distribution - The particle size distributions of suspended particulate matter generated from the two-spout silica bagging operation were measured using the Anderson IACFM particle sizing sampler. The instrument classifies particles according to aerodynamic dimensions, which is the true measure of lung penetrability (4). Anderson samples were collected in an area of 4-8 feet from the workers bagging silica on each of the three days of the field evaluation.

#### IV. RESULTS

##### A. Laboratory Quality Assurance and Performance Evaluations

###### 1) Laboratory Quality Assurance

a) High Efficiency Filters - Results of dimensional analysis measurements showed the outside diameter (OD) of the necks of all 36 plastic high efficiency filter cases evaluated, to be within tolerance of MSA's engineering design specifications. (Appendix 1) Although the OD of the necks of the filter cases were within design tolerance, many of them were found to be out of round.

b) Grommets of Motor/Blower Housing - Results of dimensional analysis showed that the inside diameters (ID) of both grommets on the motor/blower housing of all three MSA PAPR systems (47, 48, and 49) evaluated were out of tolerance (Appendix 1) and they failed to meet MSA's engineering design specifications.

As can be seen in the remarks column of Appendix 1 results of caliper measurements showed that the internal diameters of the UG's on each of the three MSA PAPR units (47, 48, and 49) deviated from the lower limit design specifications by 0.0600 to 0.0750 inches. This should result in a tighter grommet fit around the neck of the filter cases than design specifications call for. The inside diameters of both LG's on unit 47 and one of the LG grommets on unit 48 were found to be over the design (tolerance) specification by 0.0035, 0.0030, and 0.0040 inches respectively.

###### 2) Laboratory Performance Evaluation

Results of laboratory performance evaluation of the three MSA PAPR systems are given in Appendix II of the report.

The minimum air flow of the units tested was 6cfm after the four hour laboratory evaluation period which is well above the manufacturer's required operating flow rate of 4cfm.

Results of evaluation of the three MSA PAPR systems when tested under static conditions in a silica dust chamber with average challenge concentrations ranging from 50.3 mg/m<sup>3</sup> to 60.6 mg/m<sup>3</sup> showed no penetrations of particulates into the MSA PAPR systems.

## B. Field Evaluations

### 1) Personal

Reported in Table I are results of analysis for total particulates and free silica from air samples collected inside the facepiece (IFP) and outside the facepiece (OFF) of the MSA PAPR units worn by workers during the routine bagging of silica. In addition, the starting, ending, and average air flow rates (CFM) of the powered air supply unit are reported. Also given, are the calculated threshold limit value (TLV), and MSA PAPR System Protection Factors (SPF) calculated from the observed data.

The threshold limit value for the personal air samples collected OFF and IFP was calculated using the 1973 ACGIH formula for "total dust" containing Quartz (5). Because X-ray defraction analysis of the total and respirable bulk air samples collected showed the airborne particulates to which the silica baggers were exposed to consist of essentially 100% quartz, this value was used (as the % quartz in the TLV formula) to calculate the TLV.

Air flow rate measurements made before and after each a.m. and p.m. work period (when the battery packs were replaced) showed that air supply to the facepieces of the MSA PAPR was well above the required minimum of 4cfm.

Concentration of total particulates measured inside the facepiece (IFP) and outside the facepiece (OFF) ranged from 0.048 mg/m<sup>3</sup> to 1.479 mg/m<sup>3</sup> and 4.365 mg/m<sup>3</sup> to 41.681 mg/m<sup>3</sup> respectively with averages of 0.462 mg/m<sup>3</sup> and 11.495 mg/m<sup>3</sup> respectively over the three-day field evaluation period. Five of the 11 air samples collected inside the mask exceeded the calculated TLV of 0.291 mg/m<sup>3</sup>. The concentrations of all 11 air samples collected outside the facepiece exceeded the calculated TLV.

Observations of MSA PAPR systems after each work period:

MSA PAPR #47 (Filters changed and grommets cleaned following each work period)

Inspection of the MSA PAPR unit #47 after the a.m. and p.m. work periods on the first and second days showed the grommets and necks of filters to be somewhat contaminated with particulates. On the third day after the a.m. work period, unit #47 showed large quantities of particulates on the grommets and necks of filters and began penetrating into the blower housing and contaminating the air supply as evidenced by particulates which had begun to collect on the fan motor. Because the worker became ill (not exposure related), unit #47 could not be evaluated during the p.m. work period on the third day.

MSA PAPR #49 (First day - filters changed and grommets cleaned following each work period. Second and third days - filters not changed and grommets not cleaned following each work period.)

Inspection of the MSA PAPR unit #49 after the a.m. and p.m. work periods on the first day showed grommets and necks of filters to be somewhat contaminated with particulates. On the second day after the a.m. work period, unit #49 showed approximately the same contamination as during the a.m. and p.m. work periods on the first day; however, following the p.m. work period, much larger quantities of particulates had begun to build up around the grommets and necks of filters. By the end of the a.m. work period on the third day, it was observed that the particulates had penetrated into the blower housing and begun contaminating the air supply as evidenced by particulates which had begun to collect on the fan motor. (Photograph 3)

System Protection Factors (SPF) observed among the two MSA PAPR systems (47 and 49) while worn by workers working in the silica bagging operation at the two-spout bagger ranged from 8 to 182 over the three day test period.

A comparison made between both the MSA PAPR systems observed with the half facepiece and full facepiece (Table 2) showed SPF in the range from 8-182 and 14-153 for units 47 and 49 respectively when used with the half facepiece and 13-37 and 20-36 for units 47 and 49 respectively when using the full facepiece. These data reflect no real difference in the performance of the Powered Air Purifying Unit (high efficiency filters, blower, and hose assembly) of the two MSA PAPR systems.

A comparison of SPF observed between the half facepiece and the full facepiece when used with each of the two MSA PAPR's show SPF's ranging from 8-182 for the half facepiece and 13-27 for the full facepiece. These data seem to suggest that the half facepiece afforded better protection from silica dust than the full facepiece. However, insufficient data was collected to draw such a conclusion. Table 5 gives the raw field data collected during the evaluation of the MSA PAPR systems worn by workers employed in the bagging of silica.

## 2) Free Standing

Dry test meter measurements showed that the minimum air flow through the NIOSH and Illinois Minerals MSA powered air purifying units (equipped with the 76mm particulate air sampling heads rather than a respirator facepiece) was 5.7cfm and 5.9cfm respectively.

SPFs for the free standing MSA Air Purifying Units (high efficiency filter, blower, and hose assembly) were determined by dividing the total estimated ambient challenge mass (mg) of particulates by the mass (mg) collected on the 76mm air filters on the inside of the units (Table 3).



**Photograph 3.** Particulates observed on grommet, neck of high efficiency filter case and motor of the MSA PAPR system following the A.M. work period of the third day (after 1½ work shifts without changing filters or cleaning grommets or necks of filter cases)

Because the lower limit of detection (LLD) for gravimetric analysis of the 76mm filter samples was determined to be 0.3mg, the LLD value was used to calculate the SPF for the units where the filter sample weights were equal to or less than 0.3mg.

Results of gravimetric analysis of the 76mm air samples showed sample weights ranging from 0.2mg to 0.76mg and 0.1mg to 0.56mg for the NIOSH and Illinois Mineral units respectively over the three day evaluation period. As can be seen in the table, gravimetric weight gains of only two of the 76mm samples collected were above the LLD of the gravimetric analysis procedure.

### 3) Particle Size Distribution

Ambient air concentrations of particulates observed from gravimetric analysis of the Anderson samples collected on January 27, 28, and 29 showed concentrations of 5.94 mg/m<sup>3</sup>, 7.44 mg/m<sup>3</sup>, and 11.77 mg/m<sup>3</sup> respectively.

The samples obtained on January 27 and 28 with the samplers located on the side of the two-spout bagger (approximately 4 feet from the baggers) showed mass median diameters of 5.8 $\mu$ m (Figure 2) and 12.75 $\mu$ m (Figure 3) respectively and standard geometric deviations of 7.07 and 5.1 respectively. The sample collected on January 29 (approximately 4 feet from the rear of the baggers) showed a mass median diameter of 5.5 $\mu$ m (Figure 4) and a standard geometric deviation of 7.71. It is speculated that the difference in the particle size distribution observed on the 28th from that observed on the 27th and 29th is due to a malfunction of the two-spout bagger. Approximately 50 pounds of silica flour was prematurely discharged from the spout creating an unusually large cloud of suspended dust with a larger mass median diameter.

## V. DISCUSSIONS/CONCLUSIONS

From the results of data collected and visual observation made during the course of the laboratory tests and field evaluations of the MSA PAPR, it was concluded that this system did not provide the workers the required respiratory protection from exposure to silica dust during the routine bagging of silica because of the penetration of particulates into the system. We hypothesize that the penetration was the result of lateral movement between the grommets and the necks of the high efficiency filter cases caused by the movement of the worker's arm and body against the powered air purifying unit during routine bagging operations. This movement of the filter units resulted in less than a tight seal allowing the negative pressure generated by the blower inside the unit to aspirate air and particulates between the grommets and filter necks which was evidenced by the flow patterns of the particulates observed on the grommets. This leakage is substantiated by the fact that the units tested in the laboratory under static conditions showed no leakage; but when tested in the field being worn by the worker showed a leakage problem.

Although all of the grommets were out of specifications according to results of dimensional analysis (Appendix I), this did not contribute to the leakage problem because all of the upper grommets were found to be under specifications and should have provided a tighter fit around the necks of the filter cases.

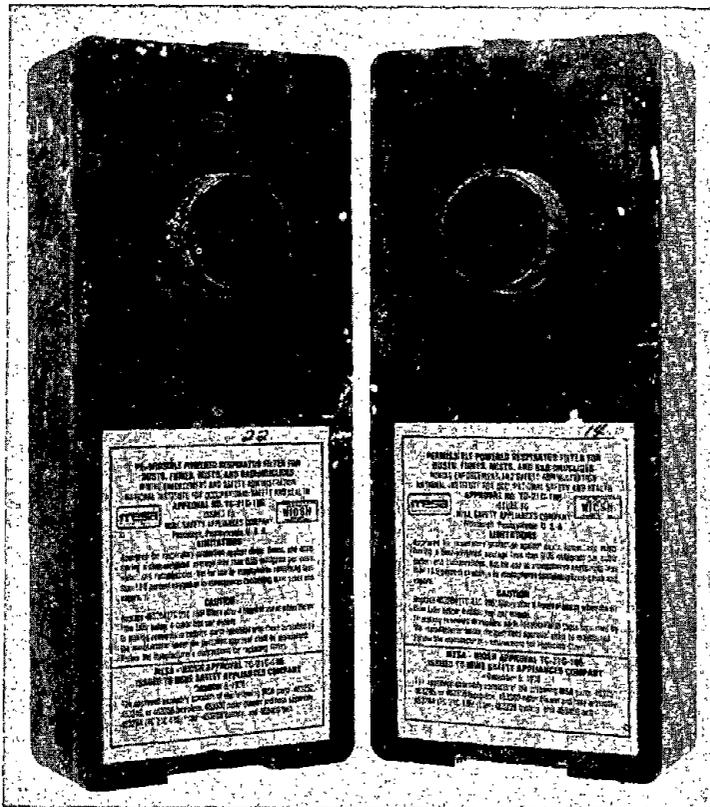
It was observed that there was no difference between the performance of MSA powered air purifying units 47 and 49 when operated under identical conditions. A comparison between these two MSA PAPR units, when tested in the laboratory and when evaluated in the field, showed that in the laboratory the units performed identically with both having observed system protection factors greater than 1000. When the same units were evaluated in the field, they again performed identically, but were found to provide poor respiratory protection as shown by the low system protection factors (ranging from 8-182) in Table 2. A comparison of the freestanding MSA powered air purifying units and the MSA PAPR's worn by the workers showed that the SPF's for the

freestanding units were all greater than those worn by the workers. However, the SPF's observed for the freestanding units were erratic ranging from 302 to greater than 2075 (Table 4). These SPF's should have been uniformly as high as those observed in the laboratory units (more than 1000). It is speculated that this variability in the SPF's observed was due to the sensitivity of the gravimetric method, i.e. the initial weight of the filter was too great for the amount of particulates collected.

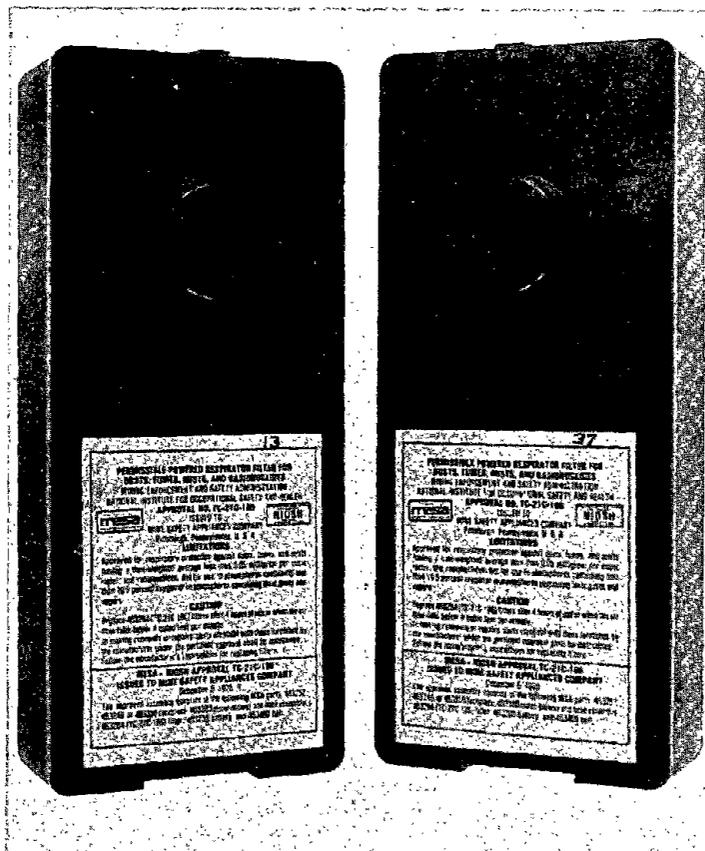
There is no clear explanation as to why the MSA PAPR units when evaluated with the Comfo II half facepiece gave higher SPF's than when evaluated with the Ultra-View full facepiece. Because the SPF's observed for the MSA PAPR units evaluated on the workers were so low (8-181) and when considering the fact that the units were leaking around the grommets and necks of the filters, the type of facepiece supplied on the unit had an insignificant bearing on the SPF's observed.

The findings of this evaluation leading to the hypothesis that particulates are penetrating the MSA PAPR units worn by the workers between the grommets and necks of the high efficiency filter cases and that this penetration is due to the intermittent/constant agitation of the unit by body motion of the worker are substantiated by the following:

- 1) substantial amounts of particulates were observed around the grommets (Photograph 3) and necks of the filter cases (Photographs 3 and 4) of units worn by the workers;
- 2) inspection of the inside of the filter cases and backs of the filters on units worn by the workers showed no evidence of penetration of particulates through the filter units;
- 3) there was no evidence of particulates on the grommets and necks of the filter cases of the three MSA PAPR units tested in the laboratory;
- 4) there was no evidence of particulate on the grommets and necks of the filter cases (Photograph 5) on the Illinois Minerals (IM) or the NIOSH (#48) free-standing units evaluated in the field in the general work area of the silica bagging operation;
- 5) the three MSA PAPR units tested in the laboratory (which did not leak) were subjected to average challenge concentrations of silica dust ranging from 50.3 mg/m<sup>3</sup> to 60.6 mg/m<sup>3</sup> with a mass median diameter of 2.2um, whereas the same units worn by workers in the field during the bagging of silica (which did leak) were subjected to average airborne concentrations of particulates of approximately 8.3 mg/m<sup>3</sup> with a mass median diameter of 5.1um to 5.5um;
- 6) the MSA PAPR units when evaluated under static laboratory conditions showed much higher System Protection Factors (more than 1000) than for those worn by workers (8-182) employed in the bagging of silica which is 6 to 125 times lower than the protection factor of 1000 specified for powered air purifying respirators by the Joint NIOSH/MSHA Standards Completion Program (August 18, 1975).



Photograph 4. Particulates observed on necks of high efficiency filter cases of MSA PAPR system worn by silica bagger.



Photograph 5. No evidence of particulates on necks of high efficiency filter cases of free standing MSA PAP units.

Upon disassembly of high efficiency filters (of the MSA PAPR initially sent to NIOSH) in the laboratory, large holes were observed (Photograph 6) in the filter fabric. Subsequent interviews with Illinois Mineral Co. employees revealed that high velocity air hoses were occasionally used to remove (blow-off) surface particulates from the PAPR units. It is reasonable to speculate that the holes observed are the result of the direct impact of high velocity air on the filter material.

It must be pointed out that the MSA flow tester provided to Illinois Mineral Co. for use in checking whether or not filters are good or bad can be misleading if hole(s) are present in the filter media. This is due to the fact that because of the free air flow, the tester will always indicate adequate air flow and therefore it would be concluded that the filter(s) is still useable.

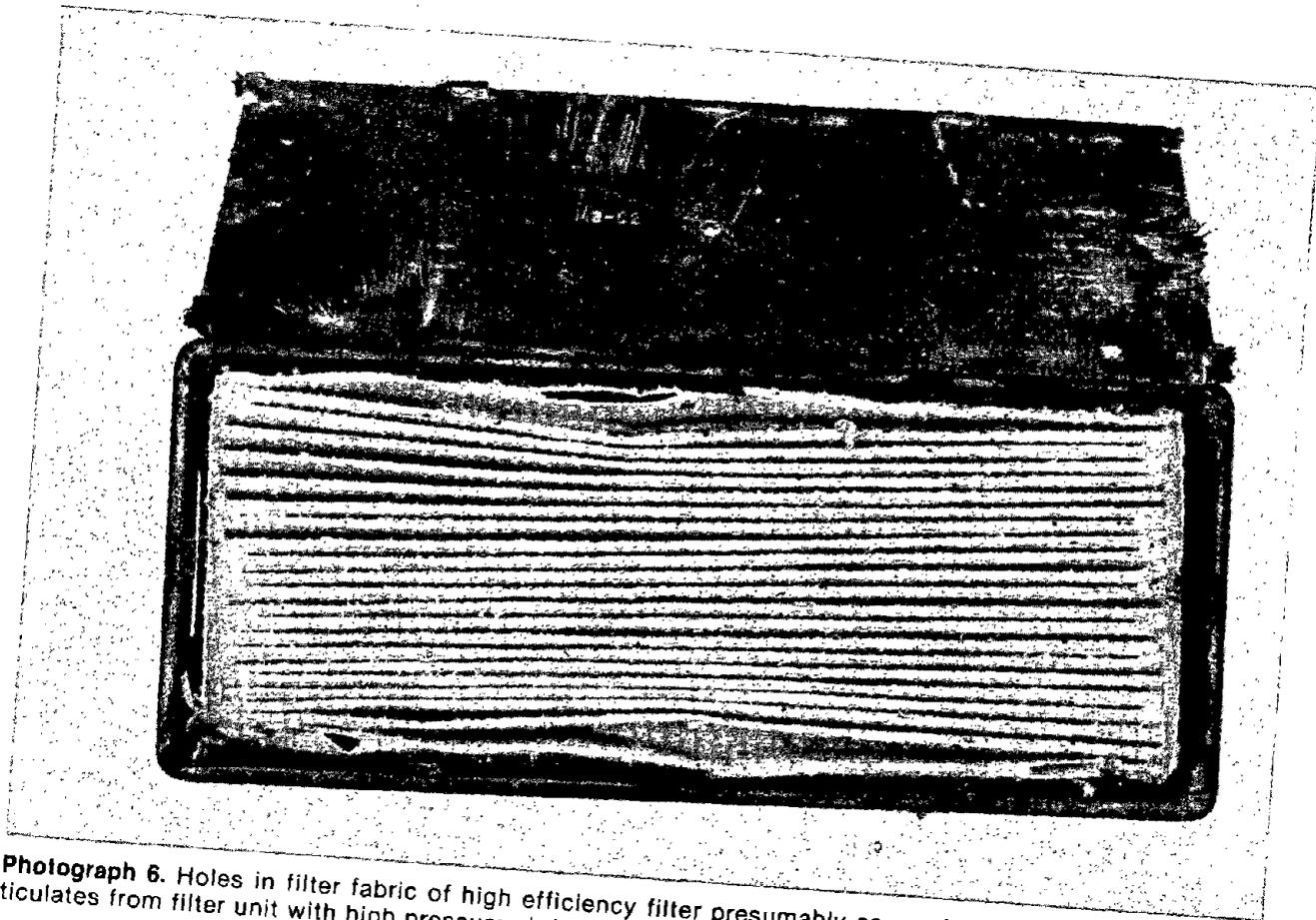
## VI. RECOMMENDATIONS

### MSA:

- 1) Discontinue recommending the use of the MSA Powered Air Purifying Respirator (PAPR) in the bagging of refined silica and similar type operations until design problems associated with and contributing to the penetration of particulates through the powered air purifying unit are corrected such that the PAPR will perform under actual field use conditions.
- 2) MSA should provide a mechanism for users to readily detect any hole(s) that may exist or develop in a filter unit. This should be in addition to the present system for determining adequate air flow through the system.
- 3) Develop/recommend a simple, efficient systematic method for cleaning the particulates from the exterior surface of the PAPR unit prior to replacing the high efficiency filters or when removing them to replace discharged battery packs.
- 4) Develop/recommend a simple, efficient, systematic method for cleaning the inside of the motor/blower housing of the PAPR unit to remove foreign material that inadvertently contaminates the unit.

### ILLINOIS MINERAL COMPANY:

- 1) Discontinue use of the MSA PAPR units until the design problems associated with the penetration of particulates through the unit are corrected.
- 2) When the use of the MSA PAPR units is resumed, insure that all components of each unit, including the facepiece, grommets, and necks of the filter cases, are thoroughly cleaned after each use. The unit should then be stored in a clean container (paper or plastic bag, etc.) to avoid contamination until used again.



**Photograph 6.** Holes in filter fabric of high efficiency filter presumably as result of removing surface particulates from filter unit with high pressure air hose.

- 3) To avoid inadvertent contamination of the inside of the motor/blower housing, use a low pressure air hose to remove particulates from the exterior surface of the PAPR unit prior to replacing the high efficiency filters or when removing them to replace discharged battery packs. The particulates should be removed in the work area and the filters and battery packs replaced in a clean area. It is recommended that this procedure be followed until the issuance of a formal method by MSA is made.
- 4) A full-facepiece respirator should always be worn by workers employed in the bagging of silica because of the potential for accidental spouting of large quantities of silica dust into their faces.

#### REFERENCES

1. Bradbury, J. C., Tripoli. Industrial Minerals and Rocks, American Institute of Mining P. 1209-1218, Metallurgical, and Petroleum Eng., Inc. 1975.
2. MSA Classification of Defects Procedure for the MSA PAPR Filter Holder (Part # 463251, Rev. #1), Drawing No. 63251, 06/14/76, Mine Safety Appliance, Pittsburgh, PA 15208, U.S.A.
3. MSA Classification of Defects Procedure for the MSA PAPR Grommet/Gasket (Part 463256 Rev. #0), Drawing No. 463256, Mine Safety Appliance, Pittsburgh, PA 15208 , U.S.A.
4. Wells, W. F., Airborne Contagion and Air Hygiene, Harvard University Press, P. 105, Cambridge, MA 1955.
5. ACGIH, "TLV's Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1973," American Congress of Governmental Industrial Hygienists, P. O. Box 1937, Cincinnati, OH 45201, 1973.

TABLE 1

PERSONAL EXPOSURE LEVELS OF SILICA DUST FROM CLOSED FACE FILTER SAMPLES COLLECTED INSIDE THE FACE PIECE (IFP)  
AND OUTSIDE THE FACE PIECE (OFF) AND SYSTEM PROTECTION FACTORS CALCULATED FROM THE OBSERVED DATA  
FROM THE MSA POWERED AIR PURIFYING RESPIRATOR (PAPR) SYSTEMS EVALUATED UNDER FIELD CONDITIONS

DATE	MSA POWERED AIR PURIFYING RESPIRATOR					PERSONAL AIR SAMPLES COLLECTED				SYSTEM PROTECTION FACTORS	TLV (mg/m <sup>3</sup> )	
	NO.	TYPE FACE PIECE	AIR FLOW MEASUREMENTS (CFM)			KIND OF SAMPLE	PARED SAMPLE NO.	TOTAL PARTICULATES		OFF IFP	30 mg/m <sup>3</sup> * % Quartz + 3	
			START	END	AVERAGE			WE. mg	Conc. mg/m <sup>3</sup>			
1/27/81	AM	47	HALF	6.09	5.19	5.64	OFF	1-1207	5.64	11.750	8	0.291
							IFP	1-1215	0.71	1.479		
	PM	47	HALF	5.89	5.61	5.75	OFF	1-1230	1.81	8.744	181	"
							IFP	1-1234	0.01	0.048		
	AM	49	FULL	5.79	5.27	5.53	OFF	1-1208	2.76	7.077	20	"
							IFP	1-1202	0.14	0.359		
	PM	49	FULL	5.79	5.70	5.75	OFF	1-1226	1.43	7.010	36	"
							IFP	1-1228	0.04	0.196		
1/28/81												
	AM	47	FULL	6.42	5.79	6.11	OFF	1-1224	3.79	8.960	13	"
							IFP	1-1227	0.29	0.686		
	PM	47	FULL	6.20	5.79	6.00	OFF	1-1221	0.74	4.933	37	"
							IFP	1-1220	0.02	0.133		
	AM	49	HALF	6.20	5.43	5.82	OFF	1-1218	6.11	16.207	102	"
							IFP	1-1223	0.06	0.159		
	PM	49	HALF	5.99	5.70	5.85	OFF	1-1219	0.55	4.365	28	"
							IFP	1-1225	0.02	0.159		
1/29/81												
	AM	47	FULL	6.31	5.70	6.01	OFF	1-1232	14.13	41.681	31	"
							IFP	1-1222	0.46	1.357		
	PM	47	FULL	NO DATA COLLECTED FOR THIS RESPIRATOR DURING THIS PERIOD - WORKER SICK								
	AM	49	HALF	6.42	5.52	5.97	OFF	1-1229	3.06	9.273	153	"
							IFP	1-1203	0.02	0.061		
	PM	49	HALF	6.09	5.61	5.85	OFF	1-1213	1.43	6.441	14	"
							IFP	1-1211	0.10	0.450		

\*Results of x-ray diffraction analysis showed total and respirable bulk air samples to contain 100% quartz.

TABLE 2

COMPARISON OF SYSTEM PROTECTION FACTORS (SPF) OBSERVED BETWEEN THE MSA POWERED AIR PURIFYING RESPIRATOR (PAPR) SYSTEMS (NO. 47 AND 49) WHEN USED WITH BOTH THE COMFO II HALF FACE PIECE AND ULTRA-VIEW FULL FACE PIECE BY WORKERS DURING THE BAGGING OF SILICA.

COMFO II HALF FACE PIECE			ULTRA-VIEW FULL FACE PIECE		
Work Period		MSA PAPR UNIT NO.	Work Period		MSA PAPR UNIT NO.
AM	PM		AM	PM	
8	181	47	20	36	49
102	28	49	13	37	47
153	14	49	31	*	47

\* No silica bagging being done by worker wearing NIOSH (MSA PAPR) No. 47 during this work period.

TABLE 3

PERFORMANCE EVALUATION OF THE MSA POWERED AIR PURIFYING UNITS (HIGH EFFICIENCY FILTER, AND BLOWER AND HOSE ASSEMBLY) WHEN OPERATED OVER A FULL WORK SHIFT, IN A FIXED (FREE STANDING) LOCATION 4-8 FEET FROM THE SILICA BAGGERS AT THE TWO SPOUT SILICA BAGGING OPERATION.

DATE	MSA PAPR SYSTEM				PERFORMANCE EVALUATION			
	UNIT NO.	HIGH EFFICIENCY FILTER NO.	OPERATING TIME (MIN)	AVERAGE OPERATING FLOW (CFM)	TOTAL CHALLENGE MASS (mg)	76mm AIR FILTER SAMPLE FILTER NO.	GRAVAMETRIC WT. (mg)	SYSTEM PROTECTION FACTORS
1/27/81	AM	48 21 & 24	222	5.7	291.719	1-1254	< LLD	> 972
	PM		178	5.8	229.868	1-1252	0.76	302
	AM	IM IA & IB	222	6.0	301.778	1-1253	< LLD	> 1006
	PM		178	5.9	237.933	1-1251	0.56	425
1/28/81								
	AM	48 30 & 40	213	6.0	289.544	1-1250	< LLD	> 965
	PM		120	6.0	163.123	1-1247	< LLD	> 544
	AM	IM IIA & IIB	213	6.1	294.369	1-1249	< LLD	> 981
	PM		120	6.3	171.279	1-1248	< LLD	> 571
1/29/81								
	AM	48 37 & 13	394	5.9	592.494	1-1246	< LLD	> 1975
	PM							
	AM	IM IIIA & IIIB	394	6.2	622.621	1-1245	< LLD	> 2075
	PM							

TABLE 4

COMPARISON OF PROTECTION FACTORS (PF) OBSERVED BETWEEN MSA PAPER UNITS WORN BY TWO WORKERS DURING THE ROUTINE BAGGING OF SILICA AT THE TWO SPOUT BAGGER AND FREE STANDING UNITS LOCATED 4-8 FEET AWAY FROM THE WORKERS BAGGING SILICA AT THE TWO-SPOUT BAGGER

DATE	WORN BY WORKERS		FREE STANDING	
	NO. 47	NO. 49	NIOSH NO. 48	ILLINOIS MINERALS
01/27/81				
AM	8	20	> 972	> 1006
PM	181	36	302	425
01/28/81				
AM	13	102	> 965	> 981
PM	37	28	> 554	> 571
01/29/81				
AM	31	153	> 1975	> 2075
PM	*	14		

\* No silica bagging being done by worker wearing NIOSH (MSA PAPER) No. 47 during this work period.

TABLE 5  
FIELD DATA COLLECTED DURING EVALUATION OF THE MSA POWERED AIR PURIFYING RESPIRATOR (PAPR)  
WORN BY WORKERS EMPLOYED IN THE BAGGING OF SILICA.

DATE	MSA POWERED AIR PURIFYING RESPIRATOR (PAPR)							PERSONAL AIR SAMPLES COLLECTED OUTSIDE THE FACE PIECE (OFF) INSIDE THE FACE PIECE (IFP)							
	UNIT NO.	TYPE FACE PIECE	HIGH EFFICIENCY FILTER NO.	PERIOD OF OPERATION	WORKER BREAK TIME (MIN)	TOTAL NET OPERATING TIME (MIN)	AVG. AIR SUPPLY RATE (CFM)	KIND OF SAMPLE	PARED SAMPLE NO.	SAMPLE PERIOD	TOTAL SAMPLE TIME (MIN)	AIR SAMPLING RATE (L/MIN)	ALL SAMPLE VOL (M <sup>3</sup> )		
01/27/81	AM	47	HALF	23 & 35	7:13 - 12:56	23	320	5.6	OFF IFP	1-1207 1-1215	SAME AS FOR MSA PAPR PERIOD OF OPERATION ←	320 320	1.5 1.5	0.480 0.480	
	PM	47	HALF	20 & 29	12:31 - 3:05	16	138	5.7	OFF IFP	1-1230 1-1234		138 138	1.5 1.5	0.207 0.207	
	AM	49	FULL	25 & 36	7:13 - 11:56	23	260	5.5	OFF IFP	1-1208 1-1202	"	260 260	1.5 1.5	0.390 0.390	
	PM	49	FULL	16 & 17	12:31 - 3:02	15	136	5.7	OFF IFP	1-1226 1-1228	"	136 136	1.5 1.5	0.204 0.204	
01/28/81															
AM	47	FULL	28 & 30	7:20 - 12:56	54	282	6.1	OFF IFP	1-1224 1-1227	"	282 282	1.5 1.5	0.423 0.423		
PM	47	FULL	14 & 22	1:00 - 2:40	0	100	6.0	OFF IFP	1-1221 1-1220	"	100 100	1.5 1.5	0.150 0.150		
AM	49	HALF	15 & 27 Used for two full shifts	7:20 - 11:53	22	251	5.8	OFF IFP	1-1218 1-1223	"	251 251	1.5 1.5	0.377 0.377		
PM	49	HALF	1/28-29/80	12:31 - 1:55	0	84	5.8	OFF IFP	1-1219 1-1225	"	84 84	1.5 1.5	0.126 0.126		
01/29/81															
AM	47	FULL	41 & 42	7:59 - 12:00	15	226	6.0	OFF IFP	1-1232 1-1222	"	226 226	1.5 1.5	0.339 0.339		
PM	47	FULL	NO SILICA BAGGING DONE BY WORKER WEARING MSA PAPR DURING THIS TIME.									"			
AM	49	HALF	15 & 27 Continued from 01/28/81	7:56 - 12:00	24	220	5.9	OFF IFP	1-1229 1-1203	"	220 220	1.5 1.5	0.330 0.330		
PM	49	HALF		12:28 - 2:55	0	147	5.8	OFF IFP	1-1213 1-1211	"	148 148	1.5 1.5	0.222 0.222		

FIGURE 1: ILLINOIS MINERALS COMPANY PLANT DIAGRAM

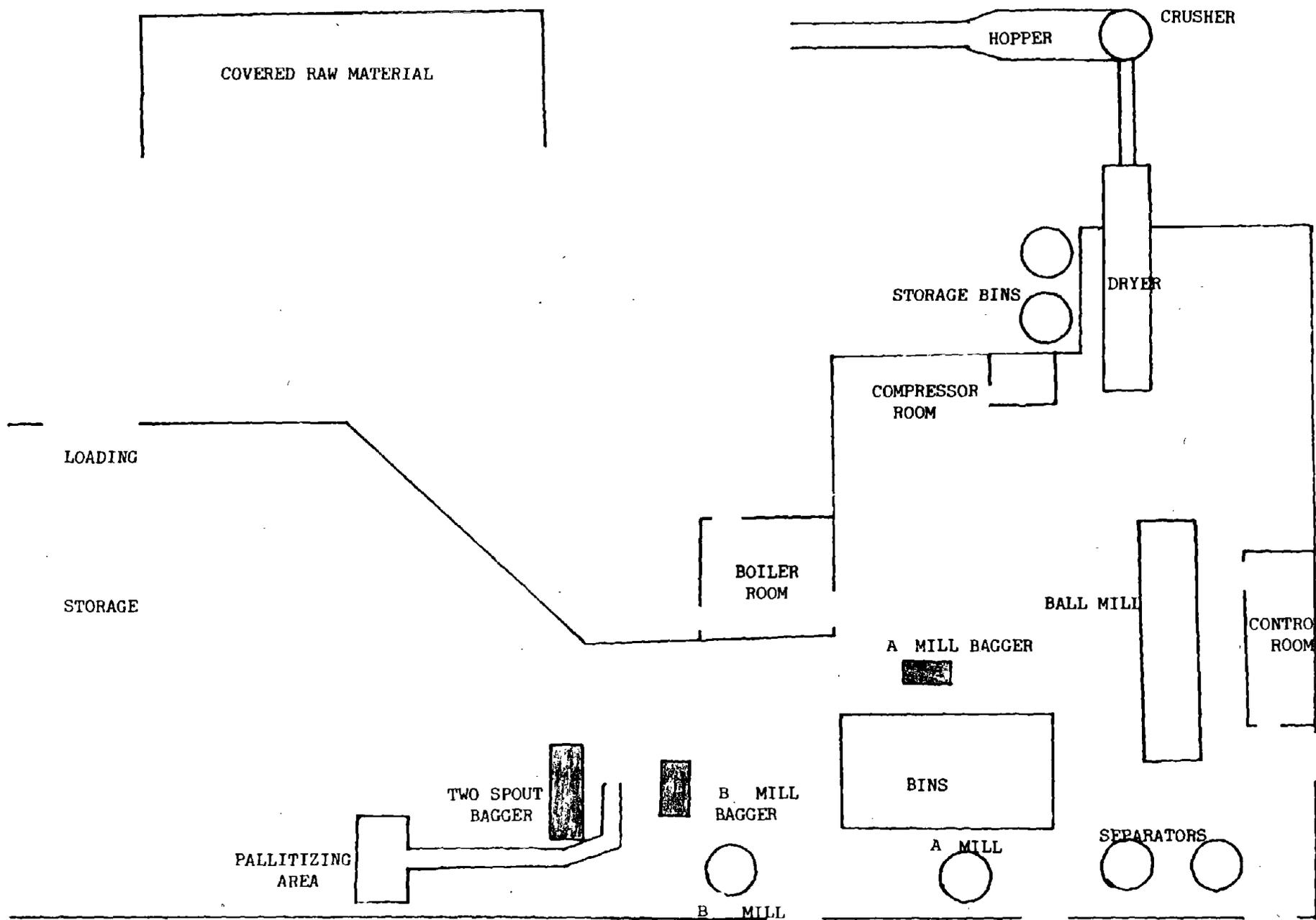


FIGURE 2 ANDERSON SAMPLE NO. 1-1240 (1240 SILICA DUST) (1/27/81)

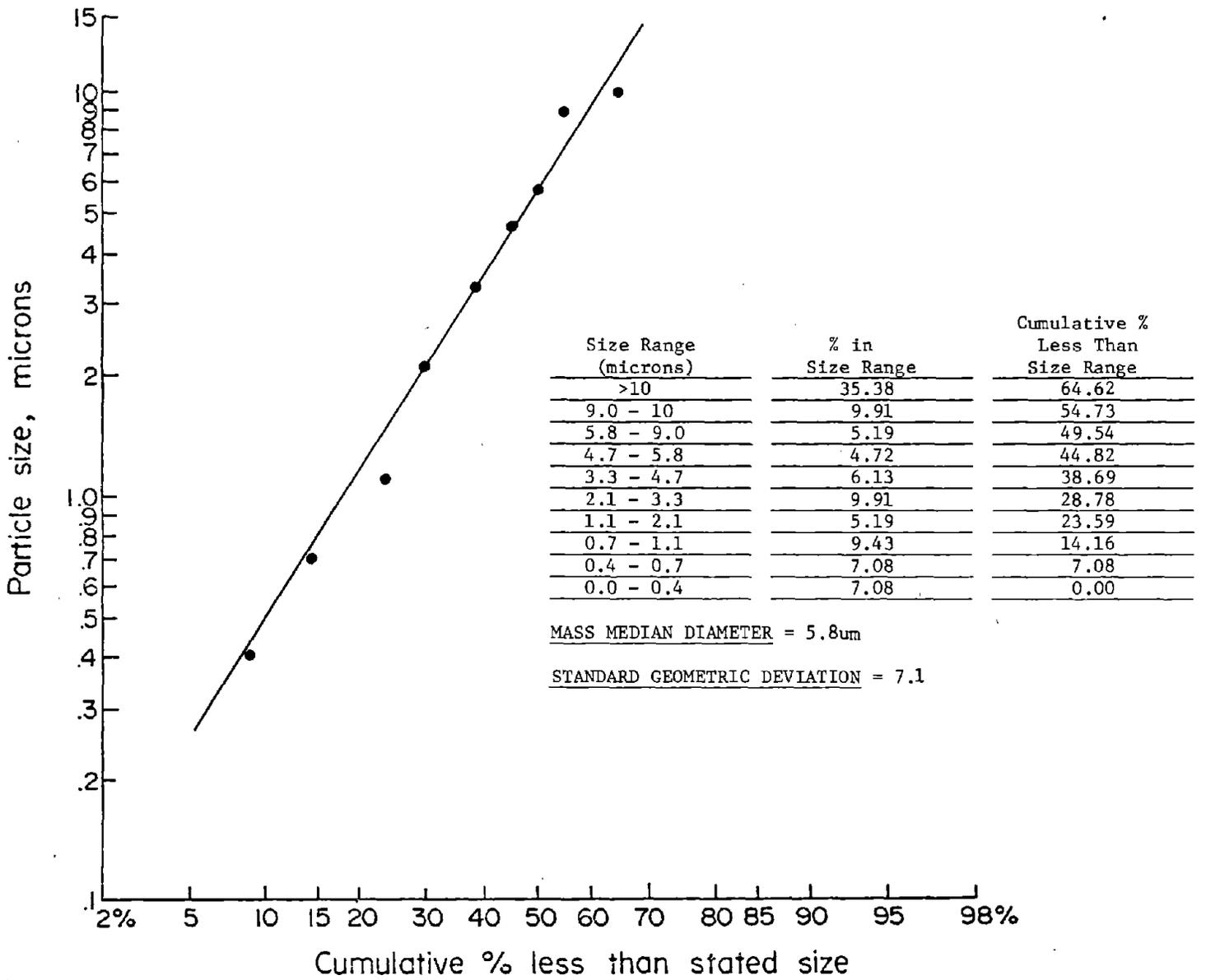


FIGURE 3 ANDERSON SAMPLE NO. 1-1244 (1160 SILICA DUST) 1/28/81

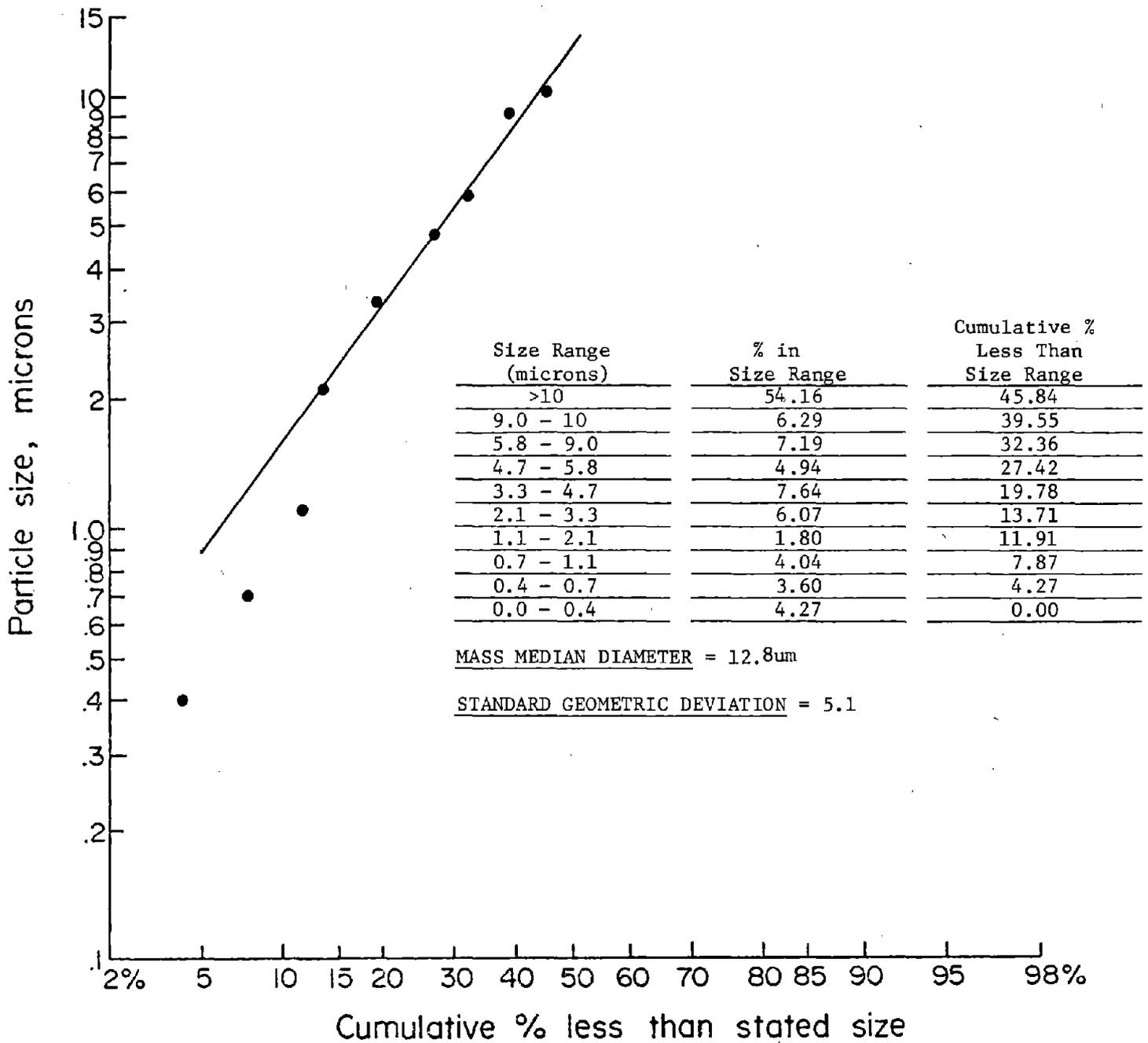
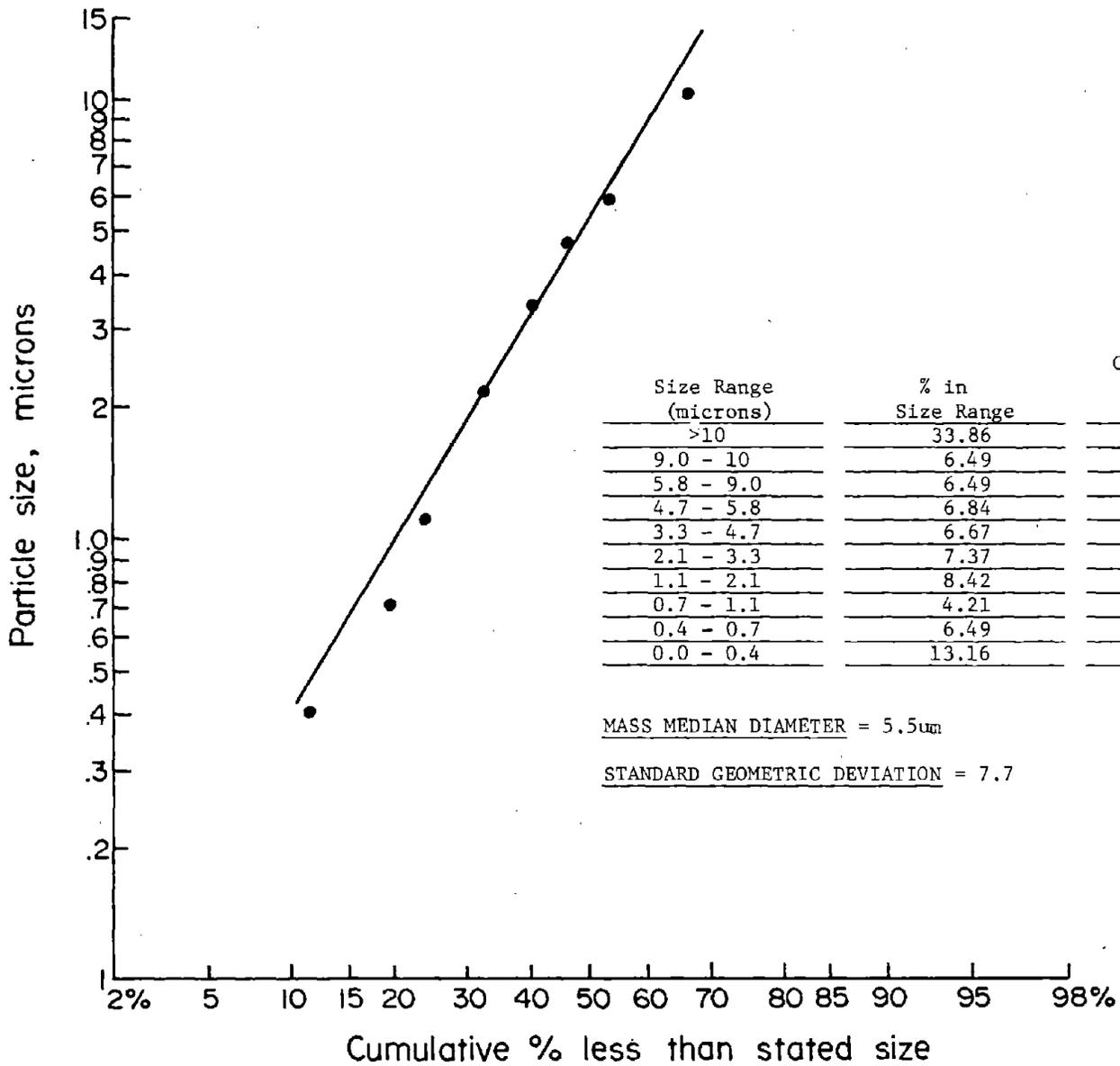
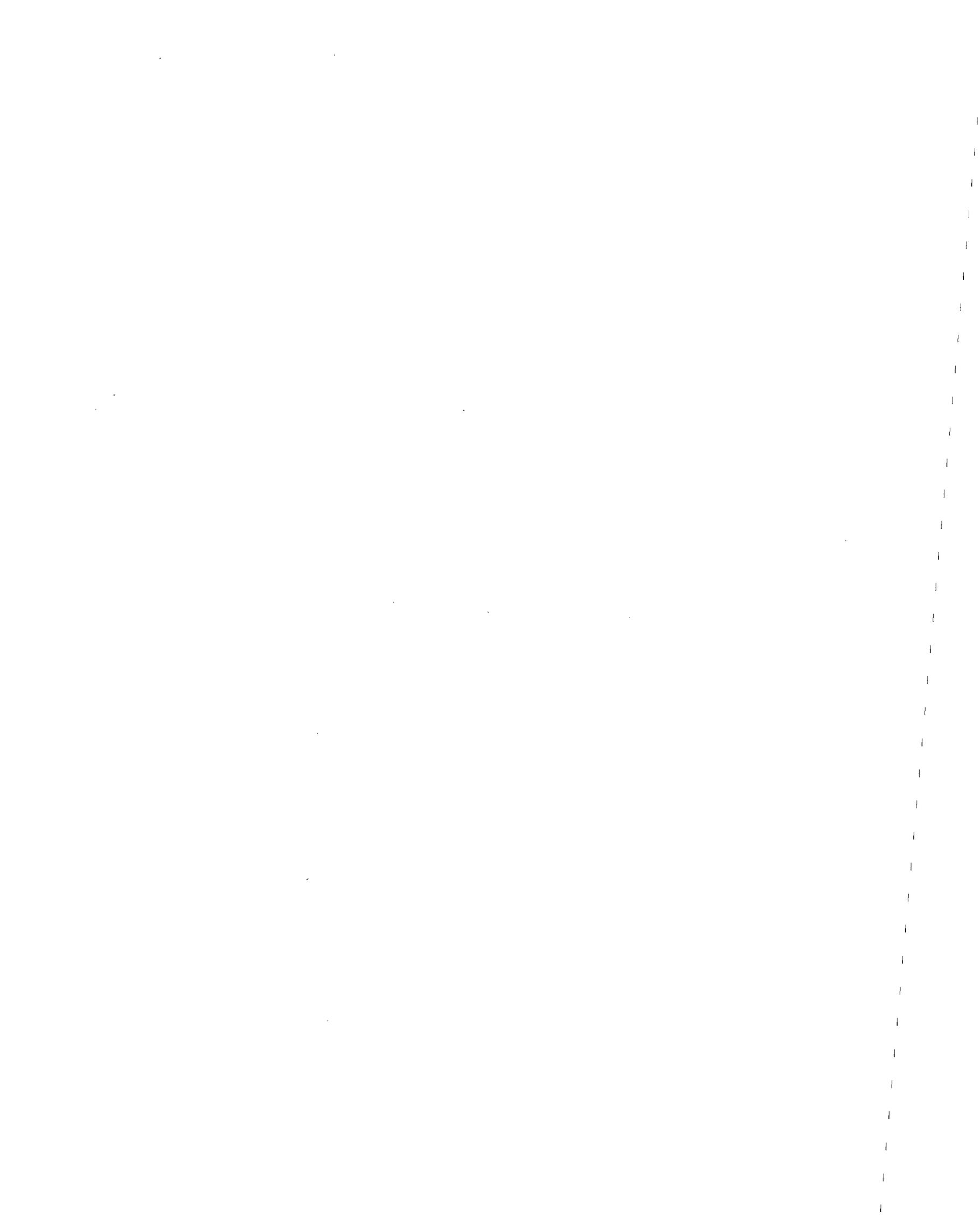


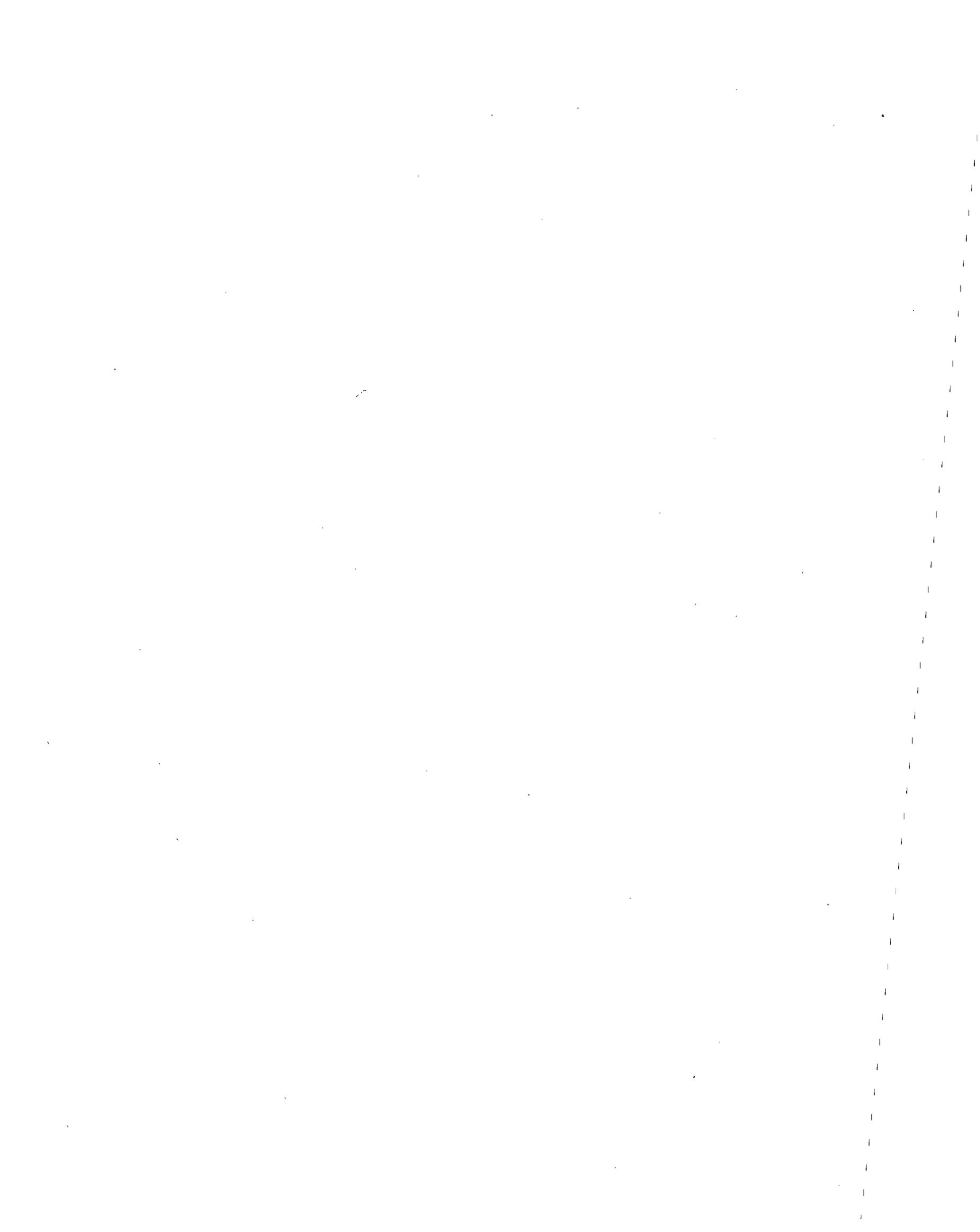
FIGURE 4 ANDERSON SAMPLE NO. 1-1239 (1240 SILICA DUST) 1/29/81



Size Range (microns)	% in Size Range	Cumulative % Less Than Size Range
>10	33.86	66.14
9.0 - 10	6.49	59.65
5.8 - 9.0	6.49	53.16
4.7 - 5.8	6.84	46.32
3.3 - 4.7	6.67	39.65
2.1 - 3.3	7.37	32.28
1.1 - 2.1	8.42	23.86
0.7 - 1.1	4.21	19.65
0.4 - 0.7	6.49	13.16
0.0 - 0.4	13.16	0.00



APPENDIX I  
Quality Assurance Test Report  
of  
MSA PAPER



QUALITY ASSURANCE TEST REPORT

MANUFACTURER Mine Safety Appliance Company (MSA) TEST DATE 01/09/81

TC APPROVAL # 21C-186 ITEM DESCRIPTION MSA Powered Air

Purifying Respirator

PROJECT # 00620 INSPECTED BY Louis T. Diaz

ITEM #	PART	DWG.#	DRAWING DIMENSION	INSPECTION RESULTS(in.)	MEASURING INSTRUMENT	REMARKS
MSA PAPR 47	Grommets	463256		1.0835 LG 1.1800 UG 1.0830 LG 1.1740 UG	Vermiers (Callipers) " "	Over Spec. by 0.0035 Under Spec. by 0.0600 Over Spec. by 0.0030 Under Spec. by 0.0660
MSA PAPR 48	Grommets	"		1.0840 LG 1.1675 UG 1.0790 LG 1.1650 UG	" " " "	Over Spec. by 0.0040 Under Spec. by 0.0725 In Spec.'s Under Spec. by 0.0750
MSA PAPR 49	Grommets	"		1.0795 LG 1.1750 UG 1.0760 LG 1.1660 UG	" " " "	In Spec.'s Under Spec. by 0.0650 In Spec.'s Under Spec. by 0.0740
MSA PAPR 47	Holder (neck) of high efficiency filter case	463251		I 1.1240 II 1.1225	"	Filter Holders (necks) of both MSA PAPR high efficiency filter cases are within design tolerance (specifications)
MSA PAPR 48	"	"		I. 1.1255 II. 1.1255	"	"
MSA PAPR 49	"	"		I. 1.1240 II. 1.1245	"	"
13	"	463251		1.125	"	Filter Holder (neck) of MSA PAPR high efficiency filter is within design tolerance (specifications)
14	"	"		1.125	"	"

QUALITY ASSURANCE TEST REPORT

MANUFACTURER Mine Safety Appliance Company (MSA) TEST DATE 01/09/81

TC APPROVAL # 21C-186 ITEM DESCRIPTION MSA Powered Air Purifying Respirator

PROJECT # 00620 INSPECTED BY Louis T. Diaz

ITEM #	PART	DWG.#	DRAWING DIMENSION	INSPECTION RESULTS	MEASURING INSTRUMENT	REMARKS
15	"	463251		1.1235	"	"
16	"	"		1.1275	"	"
17	"	"		1.1235	"	"
18	"	"		1.1270	"	"
19	"	"		1.1270	"	"
20	"	"		1.1245	"	"
21	"	"		1.1230	"	"
22	"	"		1.1280	"	"
23	"	"		1.1270	"	"
24	"	"		1.1270	"	"

QUALITY ASSURANCE TEST REPORT

MANUFACTURER Mine Safety Appliance Company (MSA) TEST DATE 01/09/81

TC APPROVAL # 21C-186 ITEM DESCRIPTION MSA Powered Air Purifying Respirator

PROJECT # 00620 INSPECTED BY Louis T. Diaz

ITEM #	PART	DWG.#	DRAWING DIMENSION	INSPECTION RESULTS	MEASURING INSTRUMENT	REMARKS
25	"	463251		1.1280	"	"
26	"	"		1.1265	"	"
27	"	"		1.1270	"	"
28	"	"		1.1265	"	"
29	"	"		1.1260	"	"
30	"	"		1.1265	"	"
31	"	"		1.1240	"	"
32	"	"		1.1270	"	"
33	"	"		1.1250	"	"
34	"	"		1.1265	"	"

QUALITY ASSURANCE TEST REPORT

MANUFACTURER Mine Safety Appliance Company (MSA) TEST DATE 01/09/81

TC APPROVAL # 21C-186 ITEM DESCRIPTION MSA Powered Air

Purifying Respirator

PROJECT # \_\_\_\_\_ INSPECTED BY \_\_\_\_\_

ITEM #	PART	DWG.#	DRAWING DIMENSION	INSPECTION RESULTS	MEASURING INSTRUMENT	REMARKS
35	"	463251		1.1240	"	"
36	"	"		1.1255	"	"
37	"	"		1.1250	"	"
38	"	"		1.1260	"	"
39	"	"		1.1230	"	"
40	"	"		1.1245	"	"
41	"	"		1.1245	"	"
42	"	"		1.1260	"	"

APPENDIX II  
Laboratory Evaluation Report  
of  
MSA PAPER







LABORATORY TEST DATA SHEET FOR SILICA DUST

Project # TN00620 Date Initiated  / /  Test # 886  
 Company MSA Test Unit MSA Powered Air Purifying Respirator with Comfo II half facepiece (Unit 49)

Action Requested Check for leakage around grommets and necks of high-efficiency filters.

Date Test Unit Received  / /  Date Tested 01/14/81

Tested to meet requirements of Title 30 subpart 11.140-4

Full facepiece resistance on back:

Resistance: Inhalation (mm H<sub>2</sub>O) Exhalation (mm H<sub>2</sub>O)  
 Initial Air Flow - 169.9 LPM = (6 cfm)

	Initial	Final	Initial	Final
--	---------	-------	---------	-------

Mask A ( )	_____	( ) _____	( ) _____	( ) _____
Mask B ( )	_____	( ) _____	( ) _____	( ) _____
Mask C ( )	_____	( ) _____	( ) _____	( ) _____

Final Air Flow - 147.3 LPM = (5.2 cfm)  
 Chamber Concentration:

Time (min)	Initial Wt.(mg)	Final Wt.(mg)	Gain(mg)	Conc.(mg/m)
0 - 10	<u>442.7</u>	<u>461.5</u>	<u>18.8</u>	<u>58.8</u>
55 - 65	<u>461.5</u>	<u>481.0</u>	<u>20.5</u>	<u>64.0</u>
115 - 125	<u>421.5</u>	<u>440.0</u>	<u>18.5</u>	<u>57.8</u>
175 - 185	<u>440.0</u>	<u>460.1</u>	<u>20.1</u>	<u>62.8</u>
235 - 245	<u>406.6</u>	<u>425.6</u>	<u>19.0</u>	<u>59.4</u>

Average Concentration: 60.6 mg/m<sup>3</sup>

	Initial wt. (mg)	Final wt. (mg)	Gain (mg)
Absolute 76mm Filter	<u>443.2</u>	<u>443.2</u>	<u>0</u>
	_____	_____	_____
	_____	_____	_____

Relative Humidity:	Initial R.H. at Time	Final R.H. at Time
Room	<u>22% @ 8:45 a.m.</u>	<u>24% @ 2:00 p.m.</u>
Chamber	<u>36% @ 8:50 a.m.</u>	<u>51% @ 1:55 p.m.</u>

Operator: Fletcher

Comments: \_\_\_\_\_



ADDENDUM TO THE  
"FIELD RESEARCH REPORT ON THE PERFORMANCE OF MSA  
POWERED AIR PURIFYING RESPIRATOR ON SILICA FLOUR  
BAGGERS AT ILLINOIS MINERAL COMPANY, ELCO,  
ILLINOIS" DATED MARCH 24, 1981

MAY 1981

## Written Responses to Points of Alleged Experimental Error

Structural integrity of MSA PAPR filters. A concern was raised by MSA of the possibility that the filtering integrity of the PAPR high efficiency filters was compromised due to the abrasive nature of the silica dust or by the surface cleaning of the filter fabric by workers using sharp objects, high pressure air hose, etc. which could have resulted in the low PF observed among the MSA PAPRs throughout the NIOSH study. As a result of this concern, the MSA PAPR filters used during the study at Illinois Minerals were tested in the NIOSH Testing and Certification Laboratories in accordance with 30 CFR Part 11, subpart 11.140-11(a), (b), and (c). This subpart outlines a filter efficiency test utilizing a thermally generated DOP aerosol with a particle size of 0.3 micrometers. Allowable filter penetration is 0.03 percent or less (i.e. a filter efficiency equal to or greater than 99.97% or PF greater than 3333). Filter penetrations measured (see Appendix III) ranged from 0.001 to 0.1 percent (i.e. PF range of 10,000 to greater than 100,000). All the filters tested passed the efficiency requirements of 11.140-11.

These results confirm that no holes developed in the structural matrix of the MSA PAPR filters as a result of use in the silica dust atmosphere and therefore this possibility could not account for the low protection factors measured.

Observation of test subjects during field study. Questions have been raised that because (1) the test subjects were not monitored over the entire 4-hour sampling period by NIOSH personnel, and (2) that the test subjects took one or two work breaks during the 4-hour sampling periods, during which time the facepiece was removed and exposed to the "ambient air", that the actual facepiece sample could be in error due to some action of the worker not monitored by the NIOSH personnel or ambient dust (silica, hair, lint, etc.) entering the facepiece sample when the facepiece was removed during the workers' breaks.

### 1) Monitoring of test subjects over 4-hour work periods

To insure as much as possible that no irregularities occur in the test subjects work regime or that the PAPR system or personal air sampling trains were not manipulated in any way so as to compromise the integrity of the air sample data collected, it is estimated that the test subjects were monitored directly by one or two of the NIOSH survey officers 100% of the time during respirator donning and doffing and break period and approximately 80% of the remaining work period. The other time being spent in gathering administrative information, preparing air sampling units and other equipment for the following work period, etc. Observation of test subjects were conducted in such a way that most of the time they were not aware of our personnel. There was no visible indicators or evidence to suggest that the MSA PAPR system or NIOSH air sampling trains were manipulated in any way so as to compromise the data collected. The workers were made aware of the importance of performing their work task in the same manner as they normally do during the course of each work day. In addition, the test subjects were told at the beginning of

each work period when the NIOSH survey officer fitted the test subjects with the PAPRs and air sampling trains that they should not remove the facepiece or manipulate the air samplers in any way. The NIOSH survey officers when not present with the test subjects were within approximately 100 - 150 feet of the test subjects' work station (silica bagging operations) at all times.

2) Removal of respirator facepieces by workers during work breaks.

In each case respirator facepieces were removed only after the test subjects had entered the shift foreman's office located adjacent to the silica bagging operation in the same building. In addition, the NIOSH survey officers routinely inspected the inside of the respirator facepieces for the presence of foreign material that may inadvertently fall into the facepiece during the break periods, none was ever observed.

If it were possible that the low protection factors measured with the respirators were the result of accidental or intentional misuse or sabotage of in-facepiece (IFP) and/or ambient (OFP) filter samples during the time the workers were not observed the following assumptions would have to be made:

- 1) Workers would have to know the mathematical relationship of the filter samples which is necessary to calculate the respirator protection factor in order to know which filter to sabotage. If the ambient (OFP) filter sample were sabotaged it would result in erroneous high estimates of PF the converse of our observations.
- 2) Workers would have to sabotage the filter samples or misuse the respirator in such a manner as not to be obviously detectable. Gross contamination of the filters would have to be avoided since such contamination would be detectable from visual examination or laboratory analysis. The weight gain of the in-facepiece samples ranged from only 0.1 mg to 0.7 mg. For these total weight gains to have been the result of sabotage would require a great deal of care and precision by each of the 4 different individual workers used during the study.

Based on the first hand experience with the Illinois Minerals workers the probability that assumptions 1 and 2 are true is very low and therefore we conclude that accidental or intentional misuse or sabotage of the respirators by the worker test subjects is not responsible for the low PFs observed with the MSA PAPRs during this field study.

Foreign matter, other than silica, on the sample filters e.g., particles in the ambient air other than silica, non-volatile remains of mucuous, phelgm or sweat."

As previously mentioned, the NIOSH survey officers routinely inspected the inside of the respirator facepieces for the presence of foreign materials that may have inadvertently fallen into the respirator facepieces when not being worn during break periods and that no foreign materials were ever observed. Due to the possibility that filter weight gains may be subject to weighing error from foreign matter collecting on the filter that was not crystalline silica the IFP and OFP personal sampler were analyzed for silica by the NIOSH technical support group in Cincinnati after the gravimetric analysis were done.

The PFs calculated from results of x-ray defraction analysis of each personal IFP and OFF air sample (Appendix IV) showed PFs to range from 16 to 248 with an average of 67. The PF calculated from results of gravimetric analysis ranged from 8 to 181 with an average of 57, as stated in the original report. This data was at the time not used because of concern about the variability in the x-ray defraction analysis techniques for silica.

Weighing errors based on equipment tolerance and/or human error.

Gravimetric errors based on equipment tolerance and human error can be estimated for the IFP and OFF air filter samples collected. This estimation can be accomplished by using the gravimetric information on the control (blank) samples used in this study.

The gravimetric analysis on all the 37 mm FUS-B personal air samplers was conducted by the NIOSH, DRDS, TSG using a Cahn model H700 automatic electrobalance housed in an environmental control chamber at  $70^{\circ} \text{F} \pm 1/2^{\circ}$  and  $50\% \text{RH} \pm 5\%$ . The lower limit of detection for the balance is  $\pm 0.026 \text{ mg}$ .

In this field study seven control (blanks) filters were used. The average control filter weight change was  $+ 0.026 \text{ mg}$  with a SD of  $0.013 \text{ mg}$ . Based on this information and the weight gains observed for the IFP and OFF samples we conclude that our mass estimates have a high degree of reliability.

Insufficient samples were collected in the NIOSH test series, to apply statistical analysis to determine the validity of the data.

The number of personal air samples necessary to adequately assess the ability of the MSA PAPR to afford adequate respiratory protection to workers employed in the silica bagging operations at Illinois Minerals was determined prior to the conduct of the field evaluation.

There was never any intent or necessity to treat the data collected statistically, but rather to compare observed protection factors (PF) with that normally expected with this type of PAPR. However, if a one sided binomial test for testing the null hypothesis  $H_0$  that the observed mean PF was greater than or equal to the expected PF of 1000 was used, then one would conclude that our observed protection factors were significantly (P less than .05) lower than the expected protection factor of 1000.

No control samples were used in the NIOSH test series and therefore unanticipated error sources cannot be evaluated.

Although not reported in the final MSA PAPR, Illinois Minerals report, seven controls (blank filters) were used. The gravimetric data presented in the report reflects net filter weight gains after corrections for the controls. The correction factor for the controls was obtained by averaging the differences in the initial and final weights of the control filters. The laboratory report of gravimetric analysis of the 37 millimeter FWS-B personal samples collected as well as the controls (blanks) are attached as Appendix V.

Appendix III

.03 Micron DOP Leakage Data on MSA PAPR Filters Used During  
the Illinois Minerals Study



**DIOCTYL-PHTHALATE TEST**

DATE: 04/14/81

TEST SHEET NO.: 1

DESCRIPTION: MSA PAPER filters TC-21C-186

FILTER UNIT	RESISTANCE (CM H <sub>2</sub> O)	AIR FLOW RATE	BREAKTHROUGH LEAKAGE %		
			UNIT	SCALE	%
		42.5			
25					.01
36					.002
37					.001
13					.001
39					.002
40					.004
24					.001
21					.006
35					.002
23					.002
17					.002
16		✓			.001

COMMENTS: Used filters from flour mill study by F.I.G.

OPERATOR: N. Bolinger & C. Coffey

**DIOCTYL-PHTHALATE TEST**

DATE: 04/14/81 TEST SHEET NO.: 2

DESCRIPTION: MSA TC-21C-186

FILTER UNIT	RESISTANCE (CM H <sub>2</sub> O)	AIR FLOW RATE	BREAKTHROUGH LEAKAGE %		
			unit	SCALE	%
30		42.5			.003
28		↓			.002
3A					.001
3B					.001
2A					.000
2B					.001
1A					.001
1B					.019
29					.000
20					.000
22					.000
14					.001

COMMENTS: F.I.G. Study

OPERATOR: N. Bolinger & C. Coffey

DIOCTYL-PHTHALATE TEST

DATE: 04/14/81

TEST SHEET NO.: 3

DESCRIPTION: MSA TC-21G-186

FILTER UNIT	RESISTANCE (CM H <sub>2</sub> O)	AIR FLOW RATE	BREARTHROUGH LEAKAGE %		
			UNIT	SCALE	%
41		42.5			.001
42		42.5			.004

COMMENTS: E.I.G. Study

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OPERATOR: N. Bolinger & C. Coffey



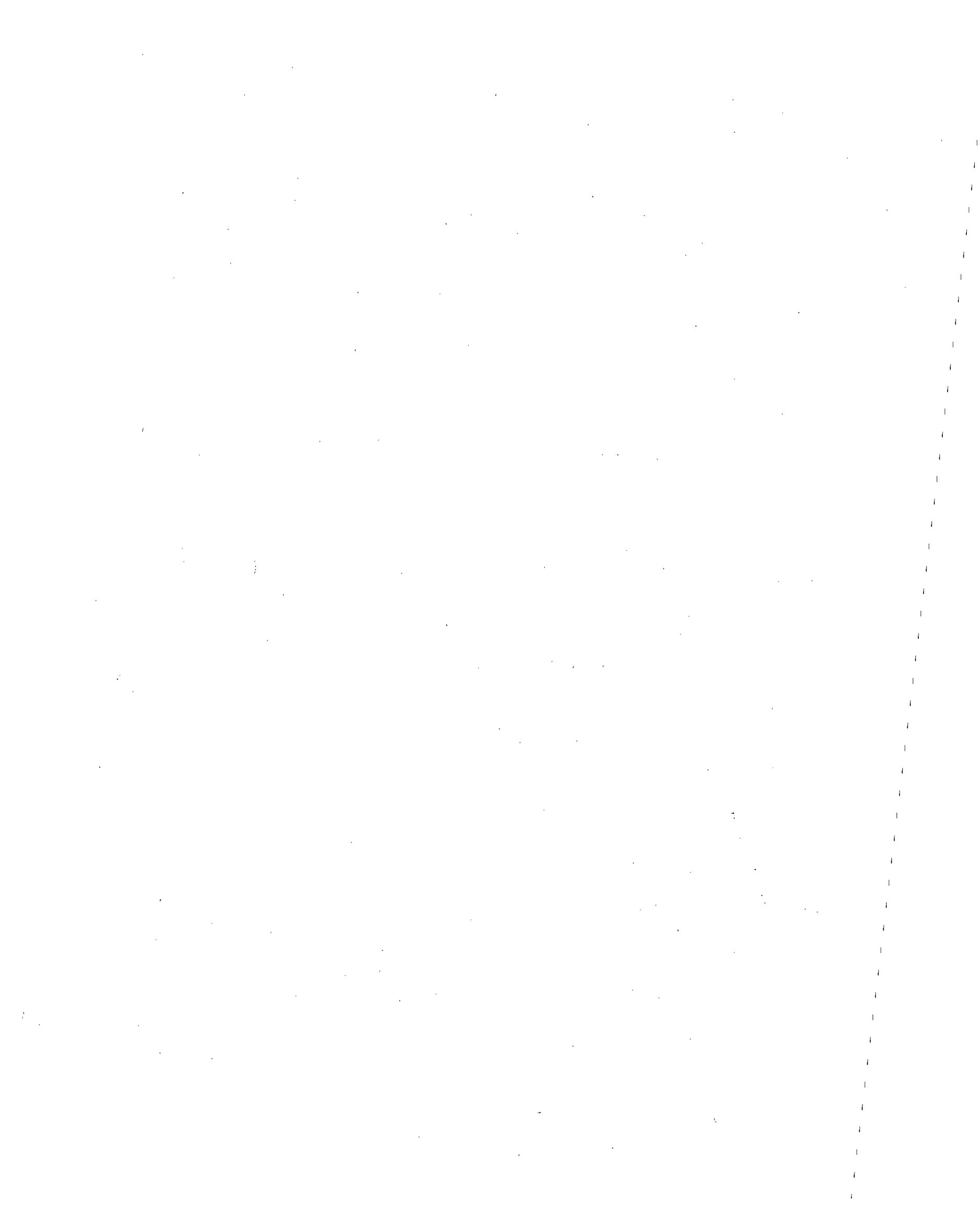
Appendix IV

Silica Analysis Data on Filter Samples



Appendix V

Filter Gravimetric Weight Data



DHHS, PHS, CDC, NIOSH, DRDS, EIB  
REPORT OF GRAVIMETRIC ANALYSIS

Sequence #	1-1-03	Project Officer: J. Perch/DSR	Type: 37mm Filter: FWS-B
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Sample Location:	Sample Date(s) and Shift(s):
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WEIGHING DATA

Balance used:	Operator	Date Samples
Ist Weight   2nd Weight	Ist Weight   2nd Weight	Weighed (2nd only):
CAHN   CAHN	G. HOLLAND   G. HOLLAND	FEB 3, 1981

ENVIRONMENTAL DATA

Temperature °F	Relative Humidity (%)		Barometric Pressure ("Hg)	
Ist Weight   2nd Weight	Ist Weight   2nd Weight			
70   72	48   48	29.15	29.15	

Number of Blanks:	7	x̄ of Blanks	+0.026	S.D. of Blanks:	.013	LLD(+)(-): 0.026
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Filter Number	Final Weight	Initial Weight	Weight Change after Correction for Blanks	Remarks (filter leakage, gross overloading, etc.)
1-1202	10.89	10.72	0.14	
1-1203	11.61	11.56	0.02	
1-1207	19.92	14.25	5.64	
1-1208	13.90	11.11	2.76	
1-1211	13.32	13.19	0.10	
1-1213	11.77	10.31	1.43	
1-1215	17.46	16.72	0.71	
1-1218	20.88	14.74	6.11	
1-1219	12.16	11.58	0.55	
1-1220	15.33	15.31	0.02	CONTROL BLANK
1-1221	14.61	13.84	<del>0.77</del> 0.74	
1-1222	14.11	13.62	0.46	
1-1223	13.87	13.78	0.06	
1-1224	14.56	10.74	3.79	
1-1225	16.10	16.08	0.02	CONTROL BLANK
1-1226	14.18	12.72	1.43	
1-1227	10.98	10.66	0.29	

